THE DESIGN, DEVELOPMENT, AND PILOT TESTING OF THE COMET HALLEY ACHIEVEMENT TEST (CHAT)

MASTER'S PROJECT

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INTRODUCTION

Background of the Study

Science educators in the United States in the 1990's will be challenged to address the growing, societal problem of declining numbers of students choosing science and engineering careers. By the year 2000, it is projected that the United States will lack over half a million needed chemists, biologists, physicists and engineers. It is also estimated that by the turn of the century 85% of new workers will be women, minorities, and immigrants who typically choose non-science or engineering careers (Changing America, 1988).

National curriculum reform programs are currently in progress to provide direction and resources to science educators, but additional efforts must be made to heighten students' interest in science. This study focused on a creative educational initiative aimed at increasing scientific literacy among older elementary students. The Challenger Center for Space Science Education (Challenger Center) is a unique institution sponsered by the families of the crew of the space shuttle Challenger. Challenger Center was created as a living memorial to the Challenger astronauts to carry on their educational mission of inspiring a generation of American schoolchildren. Challenger Center is a network of Learning Centers located in science museums, schools, and other educational institutions nationwide. As of March, 1991, Challenger Learning Centers were operating in Houston, Texas, Greenbelt, Maryland, Tampa, Florida, Dayton, Ohio, and Richmond, VA, with over twenty more cities in the application process. By 1995, 50 learning centers sites are envisioned, linked by an international headquarters in Washington, D.C.

Programs such as Challenger Center's are needed to increase scientific literacy and combat a serious lack of science competence among American citizens. According to a 1988 Educational Testing Service (ETS) report, only seven percent of the nation's 17-year-olds have the prerequisite knowledge and skills thought to be needed to perform well in college-level science courses (Science Report Card 1988). And, although the United States produces more Nobel Prize laureates in science than any other country in the world, many of the most talented students at American universities are foreigners (Fiske, 1987). Indeed, in 1988, one out of three Ph.D.'s awarded in the natural sciences and engineering went to non-American students, compared with one in four ten years ago (Tiffet, 1989).

Despite such startling statistics, there is some disagreement about the extent of the problem of science illiteracy in the United States. More specifically, there is disagreement about the effect such a problem has on business and society in general. Does good citizenship require a working knowledge of science? Those who believe it does often cite the fact that voters need to make increasingly difficult and consequential decisions about complex issues such as waste management, global warming, genetic experimentation, and a host of other important issues (Shortland, 1988, Fiske, 1987). Adding to the decision-making difficulty is the reality that scientific opinion on many key issues is often contradictory as in the cost/benefit ratio of pesticide use or nuclear power use. Many experts, however, point to the fact that many Americans have learned to incorporate a variety of technologically advanced tools into their daily lives without knowing, or needing to know, how such devices work (Saltus, 1989). These people see this as an argument that the general populace is not hampered in daily life by its rudimentary grasp of science.

There is general consensus among scientists and educators that teaching how science is relevant to daily life is important. Margaret MacVicar, dean of undergraduate education at the Massachusetts Institute of Technology (M.I.T.), makes a connection between scientific illiteracy and the way people use household items such as electronic tools and audio and video equipment. She sees a deliberate policy in engineering and design that makes a broken appliance so difficult to repair that consumers just throw it away and get a new one rather than try to figure it out. She makes the point that this adds to the perceived mystery of how things work and makes people feel that they are not in control of their own possessions. In this time of burgeoning technological advancement, it is ironic that the very things that make knowing science so important is what is turning people off (Saltus, 1989)!

Research suggests that although Americans may feel alienated from science (Saltus, 1989, Sagan, 1989), they put science and scientists in high esteem and say that, overall, science and technology have changed life for the better (Khan, 1988). Some benefits mentioned in surveys include: medical advances, new and improved products and space research. Harmful effects of science and technological advances are also cited. These include: lack of concern for the environment, the development of military weapons, food additives and dangerous drugs, and interestingly, space research (Khan, 1988).

Analysis of other data suggests major shifts in public perceptions of the importance of science in schools. From 1976-1986, regular surveys of members of service clubs and community groups found that they consistently thought the most important reason to study science was to academically prepare for the further study of science. In those ten years, however, significant increases occurred in the perceived role of science in resolving societal issues (Yager & Penwick, 1988). This increase of perceived importance of science outside the academic world can be partially attributed to the realization that science affects many aspects of daily living. Citizens find themselves facing decisions that more and more frequently require scientific judgments -from national policies on abortion to personal decisions about the risks of sexually transmitted diseases (Fiske, 1987). Uncertainty about their ability to respond intelligently to these demands seems to contribute to a feeling of powerlessness and lack of control on the part of non-scientists (Saltus, 1989, Sagan, 1989). Responding to growing concern over the level of scientific literacy of Americans, school boards, corporations, and the federal government have undertaken a number of major educational programs aimed at improving American's scientific knowledge and skills. Two major efforts are aimed at reforming school curriculum.

PROJECT 2061, started in 1985 by the American Association for the Advancement of Science (AAAS), is named after the year that Comet Halley is next projected to be visible from Earth. PROJECT SYNTHESIS is an effort born in response to a twenty year study by the

National Science Foundation (NSF) of the role of science in the American classroom.

Support for these programs geared toward increasing scientific literacy extends from the classroom to the federal government. President Bush, speaking at the Challenger Center's Gala Dinner in October, 1989, said "The mission of Challenger Center is to spark in our young people an interest -- and a joy -- in science. A spark that can change their lives -- and help make American enterprise the envy of the world."

The Mission Statement of Challenger Center specifically addresses the need to instill scientific confidence to young people. It reads: Challenger Center strives, through innovative teaching and learning experiences, to inspire and prepare students for the technological demands of the future.

Challenger Center attempts to do this by using space exploration as the vehicle to achieve its goals, which are:

- To engage and increase student enthusiasm for science, mathematics, and technology;
- To improve students' problem-solving skills and enhance their creative and critical thinking abilities;
- To teach students the importance of teamwork and communication and to develop their skills through hands-on learning activities; and

- o To foster a long-term interest in science, mathematics, and technology and inspire students to pursue this interest in their career choices.

To attain its goals, Challenger Center provides a comprehensive set of programs including:

- o hands-on experience of a realistic spaceflight simulation;
- o teacher workshops held across the country to provide teachers with stimulating tools and methods to energize the learning process;
- o classroom teleconferences that allow children in all fifty states to participate in exciting, high technology learning activities; and
- o an annual fellowship program connecting teachers with NASA scientists and Challenger Center educators to develop innovative curriculm materials.

The Challenger Learning Center in Dayton opened in the Fall of 1990 and is expected to serve approximately 10,000 students each year. The number of students served nationwide is expected to increase until, collectively, Learning Centers will be used by over a million new students each year.

The facilities at Challenger Learning Centers are designed to convey the true environment of a space mission. There are two components: Mission Control and Space Station. One-half of a student group works in

Mission Control. They guide the other half of the student group which is working in Space Station. Students are assigned to one of eight teams prior to the visit to the Learning Center and are familiarized with the tasks they will be expected to perform.

In this particular scenario the mission is to locate Comet Halley and then navigate the space station close enough to it to launch a student-built probe into the comet's tail and collect data. Mid-way through the mission, students in Mission Control go to Space Station and those in Space Station go to Mission Control.

To enhance the spaceflight experience, students participate in a number of preflight and postflight activities which are provided to the teacher. Student familiarity with material they will encounter at a Learning Center helps to make a more enjoyable and thorough learning experience. A brief postflight discussion gives students an opportunity to review the concepts they encountered.

Students' duties are communicated through a set of task cards which provide step-by-step instruction to each team. A certified science teacher, in the role of Mission Commander, is available to assist, but student teams are encouraged to try to solve their own problems by first asking questions of each other before turning to the teacher for help.

Purpose

The purpose of this study was to take the first steps toward the development of a valid and reliable 14 item multiple-choice test, to be used in the formative evaluation of the Challenger Learning Center's "Rendezvous with Comet Halley" simulation. More specifically, the purpose of this test was to evaluate student knowledge of selected scientific skills and concepts encountered through participation in the "Rendezvous with Comet Halley" simulation.

The following research question provided direction for this study: To what extent can this test be judged a valid and reliable measure of scientific knowledge of sixth grade students participating in the "Rendezvous with Comet Halley" simulation at the Challenger Learning Center located at Kiser Middle School for Environmental Science and Space Studies in Dayton, Ohio?

Definition of terms

For the purposes of this study, the following operational definitions are used:

Scientific literacy- Scientifically literate people have a basic knowledge of science and technology, particularly in the context of their own lives. They have the skills necessary to interpret new developments in science and technology and they possess the attitudes that permit them to respond actively and effectively to these developments. (Shortland, 1988)

<u>Challenger Center for Space Science Education</u> (Challenger Center)- an institution founded by the families of the crew of the Challenger space shuttle to further space science education.

<u>Learning center</u>- A hands-on educational facility where students learn about mathematics, science, technology, communication, teamwork, and problem-solving through realistic spaceflight simulations.

<u>Scenario</u>- In the learning center simulations, the hypothetical situation that defines a particular space mission, along with the curriculum materials to support it. Examples of scenarios are "Rendezvous with Comet Halley" and "Return to the Moon." syn. simulation

<u>Mission Control</u>- one of two simulator components. It monitors and guides the Space Station and supplies it with data.

<u>Space station</u>- one of two simulator components. It consists of simulated space environments where participants engage in thematic learning activities, such as biospherics, telecommunications, and life support systems.

There are eight teams involved in the mission. Their duties are:

<u>Remote Team</u>- collects leaves from plants using robots and analyzes them. Information gained will be helpful in setting up productive greenhouses on Space Station. This team also analyzes other objects collected in the

protective environment of the glovebox.

Medical Team- studies the physical and physiological effects of the zero-G world in orbit. "G" stands for the word gravity.

Isolation Chamber Team- uses teleoperations to handle and study various materials. Robots handle radioactive materials that are too hazardous for humans to handle.

Probe Team- prepares a probe to collect data before it is launched into the comet's tail.

Life Support Team- is involved with the various equipment and hardware necessary to provide air, water, and power to the Space Station.

Communications Team- asks for answers, and provides input necessary to make the mission operate smoothly.

Data Team- views comet images, and provide support in acquiring information necessary to carry out the mission.

Navigation Team- is responsible for locating the comet and guiding the Space Station to rendezvous with Comet Halley.

"The Design, Development, and Pilot Testing of the COMET HALLEY ACHIEVEMENT TEST (CHAT)" - the name of this study; a 14 item multiple-choice test designed to measure student knowledge of a variety of basic scientific concepts typically found in a general science curriculum for sixth grade students.

Limitations

This study concentrated on the design, development and pilot testing of a 14 item multiple-choice test to be used to evaluate the scientific knowledge of participants in the Challenger Center simulation, "Rendezvous with Comet Halley."

It was not the purpose of this study to administer this test in its final form or to collect comparative data. The researcher recognizes that the concept of scientific literacy is a broad one and that the "Rendezvous with Comet Halley" simulation is complex and capable of affecting students in many ways. The purpose of this study was not to evaluate the effect the simulation had on student attitudes toward the Challenger Center program or science and technology in general.

Significance of the Study

Studies show that half of all third grade students have lost interest in taking any more science and that by the eighth grade, only one in five wants to keep going (Not just, 1990). Although Challenger Center is in its infancy, its expectations are that it will make a difference in the way middle school students look at mathematics and science. It is vital to Challenger Center's success that teachers of all academic disciplines understand that the skills of problem-solving and creative thinking through teamwork, can and should be applied in their classrooms. To this end, it is important to measure what participants learn through their exposure to these teaching methods. It was the researcher's purpose in this study to construct a test that could be used to help measure the knowledge of students who experience the "Rendezvous with Comet Halley" scenario. More specifically, this measurment of knowledge gained by participants, along with existing attitudinal surveys and other evaluatiion (such as personal observation), aids Challenger Center in its efforts to increase scientific literacy levels.

It is of paramount importance that the United States works to overcome the problem of scientific illiteracy. William O. Baker, co-chair of the Project 2061 National Council, says " At stake is not only America's ability to remain in the front ranks of industrial nations, but the ability of our citizens to make informed decisions on public policy." (Science illiteracy, 1989).

Dr. James Rowley, a finalist in the Teacher in Space competition and Director of the Challenger Learning Center in Dayton, Ohio sees the Challenger Center as direct encouragement to teachers to be bold in their own classrooms. He sets as a purpose of the Center that it be a vehicle to "influence change in what happens in the classroom. We suggest to teachers that not only are these new technologies available and bound to be in their classrooms someday, but the techniques of cooperative learning and problem-solving are here now."

To help confront the scientific illiteracy problem, teachers must stretch the comfortable boundaries of their own teaching methods and strive to incorporate available, innovative techniques into their curriculum. A Challenger Learning Center represents one such innovative resource to help classroom science classes explore the creative and dynamic world of science.

CHAPTER II

REVIEW OF THE LITERATURE

The first part of this chapter is devoted to a review of the scientific literacy literature. The second part will review the professional literature concerning test construction.

Review of the literature concerning scientific literacy

There are many projects and programs in progress throughout the United States aimed at increasing the scientific literacy level of Americans. These can be loosely grouped into three categories: curriculum revision, teacher training, and out-of-classroom opportunities.

Curriculum revision. Two major efforts at national curriculum reform are Project 2061 and Project Synthesis. Both projects carry the implicit understanding that scientific literacy involves more than knowledge of past conclusions and revolves around a way of thinking and investigating.

Project 2061 is a three-phased project, sponsored by the American Association for the Advancement of Science (AAAS) designed to help reform science, mathematics, and technology education in an effort to increase students' scientific literacy level.

The purpose of Phase I is to identify the knowledge, skills and attitudes that all students ahould acquire as a result of their schooling through high school.

The purpose of Phase II is to promote scientific literacy in the schools by designing alternative curriculum models.

The purpose of Phase III is to implement the recommendations of this project (AAAS, 1989).

Phase I is complete and has been published as Science for All Americans. This report, written by the AAAS-appointed National Council of Science and Technology, has recommended two new approaches to science education: that teaching science should take an interdisciplinary approach and that ideas and thinking should be stressed rather than vocabulary and procedures.

Phase II is in progress and is expected to last two or three more years. Teams of scientists and educators are designing curricula to acheive the goals set in Science for All Americans.

Phase III, which will last ten or more years, will use the findings of Phases I and II to "move the nation toward science literacy." (Science illiteracy, 1989).

Project Synthesis has a longer history, but a similar goal in that the focus is to improve the level of science literacy of American society. In the mid-1970's public support for science and science education was at its lowest point since the 1950's (Yager, 1985). By 1976, all National Science Foundation (NSF) funds designated for science teacher educational activities were suspended and active curriculum developments were critically reviewed. At that time (1976), NSF funded three status studies: The first study was designed to assess what research suggested science education to be 1955-1975. The second concentrated on what professionals reported their curriculum to be during this time period. The third study used trained ethnographers to research what actually was taught. Later, NSF funded nine organizations to read the 3000 pages generated by these three studies.

Finally, Project Synthesis was established as a major research effort exploring four areas:

1. science for affecting daily living
2. science for resolving societal issues
3. career awareness in science and technology
4. science for further study (academic preparation)

Public opinion surveys conducted between 1976 and 1986 have continually confirmed the above goals as reasons for including science in K-12 programs of all learners (Yager & Penwick, 1988).

Teacher training programs. Staff development is basic to any educational reform. The quest to increase the scientific literacy level of all students is aided by a variety of training programs for teachers. Much of this training is focused on teaching teachers to use computers and other media technologies in their classrooms on a regular basis (Okey, 1984, Martin, 1986).

Another type of program encourages collaboration between teachers and existing local resources. For example, rural elementary school teachers in New Mexico interested in improving science instruction are becoming involved in a five-part program utilizing the strengths of the New Mexico Center for Rural Education and the New Mexico Museum of Natural History (Dacus & Hutto, 1989).

Efforts include summer workshops on science and society issues which attempt to prepare teachers to effectively discuss controversial subjects such as human genetics and bioethical decision-making. One such project includes inservice follow-up programs where inservice workshops for participant's peers are implemented (Mertens & Hendrix, 1988).

One other attempt to assist teachers in improving science teaching practices is an applicaiton of coaching, where an experienced science teacher is assigned to provide personal support and technical assistance to a less experienced science teacher (Tobin & Espinet, 1989).

Out-of-classroom opportunities. Opportunities to learn science outside of a classroom are many and varied and they go beyond the familiar science and natural history museums. One currently popular suggestion utilizes the powerful relationship between the American people and the media. It is thought that science literacy efforts would be enhanced by training journalists to specialize in science issues (Kapitza, 1988, Pockley, 1988).

Even people who write for professional science journals should be encouraged to present all sides of a controversial issue in the interest of complete research rather than writing to further a personal viewpoint.

Popular scientific journals, such as "Scientific American" and "Discover" are readily available to anyone interested in current science issues. These journals, by design, tend to relate scientific current events in an easily readable and interesting style (Kapitza,1988).

There are museums across the country, open to the public, that encourage people to participate in the exhibits through hands-on activities. Examples of such museums are the Center of Science and Industry (COSI) located in Columbus, Ohio and the Children's Museum located in Indianapolis.

Another approach, though an indirect one, is to seriously improve teacher incentives, motivation, and competence. Carl Sagan (1989) points out that since property taxes are not used for any other large need such as the military budget, agriculture, or toxic waste clean up, why should we expect to support education this way? He suggests that education be supported from general taxes on state and local levels or from a special education tax on industries with special needs for technically trained workers (Sagan, 1989). As discussed earlier, these industries face an unmet need in the future.

Elements of curriculum revision, teacher training and out-of-the-classroom opportunities can be combined to provide an interesting and effective program. Challenger Learning Centers use all three methods in an attempt to increase scientific literacy among middle school students. At the very least, a visit to a Learning Center is an out-of-the-classroom experience and teachers and students are usually enthusiastic and ready to enjoy the spaceflight. This is a desirable frame of mind in which to learn science.

The inclusion of preflight and postflight curriculum material makes the overall visit to the Learning Center more meaningful than an isolated exposure to the simulation. The provided material encourages the use of teamwork and problem-solving skills inside the classroom- this kind of curriculum revision also serves as a form of teacher training.

A trip to a Challenger Learning Center also exposes teachers to technologies such as interactive video and computer networking. The visit provides an opportunity to teach and learn on equipment they may otherwise not have a chance to use.

Review of Literature concerning test construction

To help the Challenger Learning Center provide the most meaningful experience possible, it is necessary to determine what knowledge students gain from participating in a mission.

Student assessment is not an exact process and much has been written about teachers' ability to construct well written items. In general, an effective test measures how well a particular student has mastered the stated learning objectives (Gentry, 1989, Johnson, 1989). An effective test contains clearly written test items that are both reliable and valid. Reliability refers to replicability- Would the student get the same score on an equivalent test? Validity refers to the test information- Does the test assess the appropriate material (Johnson, 1989)?

To aid the reliablilty factor in teacher-made-tests, the National Council on Measurement in Education (NCME) has designed a module explaining test reliablity requirements (Frisbie, 1988). Validity of a teacher-made-test is most often compromised by students "test-wiseness". This term refers to the ability of a test-taker to figure out a correct response using secondary clues . These could be, for example, redundant choices (Childs, 1989), clues in the body of the question, varying length of responses (the correct one tends to be the longest), or the use of absolutes (all, never) in distractors (Johnson, 1989). According to Johnson (1989), another factor affecting validity lies in the readability of the test. If a test is hard to read, it is the reading ability of the test-taker being evaluated, not science ability. If an equally hard to read test were administered a second time, the test-taker would probably perform at the same level. In this case, the test would be reliable, but invalid.

Being wary of test-wiseness, then, research shows that correctly constructed achievement tests provide objective feedback as to what students are learning and understanding and that the most "instructionally relevant" tests are custom-made to emphasize certain, specific information (Childs, 1989). The need to evaluate certain, specific science concepts presented in the "Rendezvous with Comet Halley" scenario, lent itself to the development of a 14-item multiple choice achievement test.

There are several advantages to multiple-choice tests over other types of objective assessment. Multiple choice tests can measure different levels of learning as defined by Bloom's Taxonmy and they can easily include evaluation of many learning objectives (Johnson, 1989). They can accurately discern areas of student difficulty if distractors are written to include common misperceptions. Multiple-choice tests can be used to initiate meaningful post-test discussion, especially if the discussion includes explanation of why correct responses are right and incorrect responses are wrong (Clegg & Cashin, 1986).

Other strengths of multiple-choice tests are that they can be administered and graded with ease and can be constructed so as to make a correct guess unlikely, especially as compared to a True/False test.

There is a great amount of overlap in publication as to how to construct effective multiple-choice test items. All of the following reccommendations appeared in more than one article, but were all included in an IDEA paper written by Clegg and Cashin, 1986.

- Concentrate of evaluating higher levels of thinking. This usually takes more time.
- Write the stem first and include in it all information necessary to determine the problem.
- Avoid repeating phrases in the responses. Include repetitive words in the stem.
- Write the correct or best response after writing the stem.
- Take the time to write challenging distractors. The integrety of a test is weakened by poorly written incorrect options.
- Distractors should all be plausible options. Their purpose is to discriminate between correct or important information and incorrect or irrelevant information.

- Be wary of writing secondary clues.
- Use consistent grammar between stem and responses.
- Check that correct responses are not consistently longer than incorrect options.
- Layout of the test should be that all options are arranged vertically on separate lines, options should distinguished using capital letters (A,B,C,D), and correct answers should be randomly positioned (Clegg & Cashin, 1986).

Review of the literature on scientific literacy and on test construction led the researcher to conclude that a multiple choice achievement test would best serve the purposes of this study.

CHAPTER III

METHODOLOGY

Purpose

The purpose of the Comet Halley Achievement Test (CHAT) was to measure the knowledge gained by students after participating in the "Rendezvous with Comet Halley" simulation. All information contained in the first part of the test was presented to the students prior to the actual simulated spaceflight, either in the classroom before visiting the Challenger Learning Center (CLC) or in the pre-flight lecture provided by the Mission Commander just before the simulation began.

The test items dealing with the specifics of duties of a particular team reflected work performed while at the team's station. Test results from a final form of the CHAT will highlight the relative strength of various areas of the simulated spaceflight experience.

It was the hope of the researcher that such data aid Challenger Center in assessing the value of pre-flight classroom lessons, on-site pre-flight lectures, and most importantly to Challenger Center, the effectiveness of teaching scientific concepts in the "hands-on" nature that is the basis of the Center.

Design Criteria for the Comet Halley Achievement Test (CHAT)

Construction of the CHAT was guided by the following design criteria which were established by the researcher:

1. that CHAT provide a valid and reliable test for the purposes of evaluating knowledge of students participating in the "Rendezvous with Comet Halley" simulation.
2. that the format and language be familiar to sixth-grade test takers. It was important that the students not spend time or effort figuring out how to take the test.
3. that the time availabe to take the test not exceed fifteen minutes. Schools typically do not have the time availabe for a more thorough, time-consuming evaluation.
4. that the CHAT follow the educational objectives already developed by Challenger Center staff. These educational objectives were included in the Pre-visit/Post-visit Education Package that was distributed to all participating teachers.
5. that test items represent various levels of thinking in the cognitive domain of Bloom's taxonomy (Bloom, 1956). Specifically, at least five items were written at the Application level. For example, the Life Support Team members were asked one lower-level Knowledge question concerning light energy and one higher-

level Application question where they had to decide how to neutralize water (See Appendix A).

Reliability

The reliability of a test is a measure of its degree of internal consistency. That is, a student taking a reliable test will earn about the same score each time the test is taken with variance accounted for by being random error.

Reliabilty is essential to achieve any kind of accurate measurement and it is imperative that researchers utilize techniques to help determine to what extent their measuring instruments are consistent or reliable (Ary et al., 1985).

There are a number of procedures that measure the reliability of a test. The researcher chose the Kuder-Richardson formula 20 (KR-20) for several reasons. First, the KR-20 is a well-known method of measuring tests for internal consistency. Second, using the KR-20 required only one administration of the CHAT. And third, because results were computer-analyzed, it was the most time-effective method of generating a reliablity coefficient.

It was a goal of the researcher to reach a reliability coefficient of .60 or higher on the CHAT.

Validity

In addition to reliabilty, the other important characteristic of a test is validity. Validity is concerned that the test measures what it intends to measure.

In developing the CHAT, the researcher was concerned with the content validity of the test. Content validity refers to the extent to which a test contains a representative sampling of the pertinent content. Since it was impossible to cover all the possible content on the test, it was important that the CHAT adequately represent the topics and cognitive processes covered during the "Rendezvous with Comet Halley" spaceflight simulation.

One method commonly used to establish content validity is the concensus of a panel of experts (Ary et al., 1985). In developing the CHAT, the researcher used a panel of three experts. Two of these experts were teachers working with students daily at the Challenger Learning Center (CLC) and the other was the director of the CLC. An extensive review process resulted in several revisions of the CHAT. Every stem and distractor was critically examined by the panel and the agreement of the entire expert panel was required for the inclusion of each item on the CHAT.

For research purposes, each test item was referred to the "Rendezvous with Comet Halley" learning objectives. For inclusion, it was necessary that each test item be addressed in one of the learning objectives. If the content involved wasn't included, the test item was eliminated even if it contained relevant, important information. For example, an early draft of the CHAT contained a question concerning the advantages of a space station mission as compared to a space shuttle mission. Although the expert panel concurred that the item contained pertinent information, it was deemed inappropriate for the CHAT because the learning objectives did not contain information about the space shuttle program. A copy of these learning objectives is included as Appendix B.

Each item on the CHAT can be placed in one of four broad categories:

1. Understanding and application of information about comets.
2. Understanding of roles and responsibilities required to carryout a successful space mission.
3. Understanding team roles and responsibilities in the Comet Halley mission.
4. Understanding and application of concepts used by particular student teams.

The first three categories are headings used in the mission's learning objectives. Test items 1, 3, 6, and 10 referred to the first category. Test items 2, 5, 8, and 12 referred to the second category. Test items 4, 7, 9, and 11 referred to the third category. Test items 13 and 14 were customized to be applicable only to a member of a specific team and refer to the fourth category above.

Establishment of the Format of the CHAT

Four test items were written for each of the three staff-developed learning objectives for a total of 12 items. Items 13 and 14 were content-specific to each student team. This resulted in eight forms of the CHAT; each form contained 14 items out of the total 28 items. That is, all forms contained identical items 1 through 12 and two additional items, items 13 and 14, that focused on concepts of the individual test-taker's team.

A sentence completion, multiple-choice format was used in the CHAT as sixth-grade students are familiar with this type of evaluation. The panel of experts reviewed the test with an eye toward finding vocabulary inappropriate to sixth-grade test-takers. Each test item contained a stem in which all pertinent information is included and four responses. The letters of correct responses were randomly assigned.

Conditions of Testing

The test population for the pilot-testing of the CHAT was drawn from classes of sixth-grade students visiting the CLC in March, 1991. Those attending the CLC represent Dayton Public Schools, a predominantly urban district, and seven suburban school districts. For the purposes of pilot-testing the CHAT, four classes from Dayton Public Schools were tested. To maintain the atmosphere normally present during a simulation when testing is not included, and to reduce any possible test anxiety, students were not informed that they would be tested on the spaeflight experience prior to their visit.

The pilot-testing was conducted immediately after the simulation was completed in a teacher-supervised, well-lit, quiet environment.

Data Analysis

Results produced from the pilot-testing of the CHAT were analyzed using the Statistical Package for the Social Sciences (SPSS). Specifically, this analysis included a test for internal consistency employing the KR-20 formula. Since it was the purpose of this study to take the initial steps in the preparation of a reliable measure of achievement, data was gathered for later report on each of the 28 items including the reporting of information on item difficulty, item discrimination, and the frequency of response.

Acceptable values for item difficulty for all types of written tests are about 50% and are about 65% for a multiple-choice test (Oosterhof, 1990). Acceptable values for item discrimination for a teacher-made test are around 20% with any value near 40% considered to be excellent.

Items on the CHAT that were analyzed to have an item difficulty value of 40% or above were considered to be acceptable. An item discrimination value of 20% or above was considered to be acceptable.

CHAPTER IV

RESULTS

In this study, the researcher sought to gain insight on the reliability and validity of the Comet Halley Achievement Test (CHAT). Test data were analyzed for reliability employing the Kuder-Richardson Formula 20 (KR-20) using the Statistical Package for the Social Sciences (SPSS) computer program. The CHAT was examined for content validity through the concensus of a three member panel of experts. The researcher was also interested in item analysis with particular attention being paid to item difficulty and item discrimination. This data was computer-analyzed for the first 12 of the 14 items on the CHAT and hand-calculated for the eight different forms of items 13 and 14. Each of the eight student teams had a form of the test on which items 13 and 14 tested knowledge applicable only to that team.

Reliability of the CHAT

Analysis of the CHAT using the KR-20 formula produced a reliability coefficient of .61. Out of a total of 14 test items administered to a total of 109 students, the mean raw score was 8.28 (59%). The standard deviation was 2.46. Maximum score was 14 and minimum score was 2, yielding a range of 12.

Item Analysis

Item difficulty. The item difficulty of an item refers to the percentage of students who answered the item correctly. The range of item difficulty goes from 0% to 100% with a value around 65% desirable for a multiple-choice test (Oosterhof, 1990). To aid computer analysis, the correct response on items 13 and 14 were assigned the same letter on all eight forms of the CHAT which yielded an average value of item difficulty for these two items. The researcher subsequently did hand-calculations of the item difficulty for each different item 13 and 14 to produce a more detailed analysis. This calculation was made by dividing the number of students who answered the item correctly into the total number of students administered this test item.

students answering correctly / # students administered this item = item difficulty.

The item difficulty for all 28 items can be found on Table 1.

Item Discrimination. The item discrimination of an item refers to its ability to distinguish between the more and less knowledgable students. A common method used to determine a numerical value for item discrimination is to first identify the 25% of the students who earned the highest scores as the upper 1/4 and the 25% of students who earned the lowest scores as the lower 1/4 and then compare the scores on particular test items. This comparison is made by finding the difference in percentages of students in the upper and lower groups who answered the item correctly.

TABLE 1
Item difficulty values of the Comet Halley Achievement Test

Item Difficulty	Number of Students Answering Item Correctly	Number of Students Administered the Item	
1	81	109	74%
2	59	109	54%
3	89	109	82%
4	91	109	84%
5	46	109	42%
6	93	109	85%
7	71	109	65%
8	50	109	46%
9	20	109	18%
10	40	109	37%
11	63	109	58%
12	83	109	76%
13 (Probe)	9	16	56%
14 (Probe)	7	16	44%
13 (Life Supp.)	7	16	44%
14 (Life Supp.)	8	16	50%
13 (Isolation)	14	16	88%
14 (Isolation)	6	16	38%
13 (Medical)	11	15	73%
14 (Medical)	10	15	67%
13 (Communic.)	7	8	88%
14 (Communic.)	7	8	88%
13 (Navigation)	1	16	6%
14 (Navigation)	3	16	19%
13 (Remote)	10	14	71%
14 (Remote)	7	14	50%
13 (Data)	7	9	78%
14 (Data)	5	9	56%

That is,

% correct from upper group - % correct from lower group = item discrimination percentage.

The range of discrimination values is 100% to -100%. On a teacher-made test, a value of 20% is considered to be acceptable and a value of 40% considered to be excellent. Item discrimination values for 14 items are reported on Table 2. An average value for items 13 and 14 is included.

TABLE 2
Item discrimination values of the Comet Halley Achievement Test

Item	Item Discrimination
1	46%
2	72%
3	46%
4	22%
5	62%
6	38%
7	61%
8	44%
9	11%
10	62%
11	53%
12	37%
13 (average all forms)	52%
14 (average all forms)	49%

Following is a brief analysis of each of the test items administered to 109 students.

ITEM 1

On Item 1, which queried students on the importance of studying Comet Halley, 81 students (74%) correctly answered that it was to help learn about the beginnings of the solar system. The discrimination value was 46%. Each distractor was chosen by at least 5% of the test takers.

ITEM 2

On Item 2, which tested students' knowledge of what a space station is, 102 students (93%) knew that it was a laboratory, although only 59 of them (54%) correctly answered that this type of laboratory was located in space. The discrimination value was 72% and, among the total group, every distractor was indicated as a correct response.

ITEM 3

Item 3 questioned what materials Comet Halley is made of and 89 students (82%) correctly responded that comets are composed of rock, ice, and gas. The next most frequently chosen response, (13 students or 12%) included snow as a composition material. This is probably due to the fact that comets are very often referred to as "dirty snowballs." The discrimination on this item was 46%, and each distractor was chosen as a correct response.

ITEM 4

On Item 4 which asked the test-taker to identify one important job of the Isolation team, 91 students (84%) knew that using robots to handle hazardous materials was the correct response. Item discrimination was 22%. All distractors were chosen as a correct response even though none of the distractors described jobs performed by the Isolation Team.

ITEM 5

Item 5 questioned the most important job of the people in Mission Control. It had as a companion, Item

8 which questioned the most important job of the people in Space Station. It was the hope of the test-maker to make an important distinction that those in Space Station were doing experiments and so had to follow directions very carefully and those in Mission Control were responsible for recording the results of the experiments, with both groups keeping communication flowing. Forty-six students (42%) correctly answered this item, although 37 students (34%) answered that it was most important for Mission Controllers to answer questions from Space Station and ask what Space Station was going to do next. Item discrimination was 62% and at least 5% of students chose each distractor.

ITEM 6

On Item 6 which was concerned with the parts of a comet, 93 students (86%) correctly identified these as the nucleus, coma and tail. Item discrimination was 38 % and all distractors were chosen as a correct response.

ITEM 7

On Item 7, students were queried as to one important job of the Navigation Team and 71 students (65%) correctly responded that it was to find Comet Halley in space and launch a space probe into it. To avoid the subjective nature of importance, none of the distractors described jobs performed by the Navigation Team. Still, all distractors were chosen by at least 7% of the test-takers. Item discrimination was 61%.

ITEM 8

Item 8 questioned students on the most important job of people working in Space Station. As explained in the analysis of companion question 5, item 8 sought to differentiate between duties in Space Station and Mission Control. Fifty students (46%) correctly responded that following directions was this group's most important job while 37 students (34%) chose that distractor that described Mission Control's most important job- that of recording data. The item discrimination value was 44% for this item.

ITEM 9

On Item 9 which asked students to choose one important job of the Medical Team, only 20 students (18%) correctly responded that it was to study the physical effects of living onboard a Space Station. This was the third most frequently chosen response falling behind taking care of anyone who is sick which 46 (42%) students chose and making sure that crew members have clean water and air to prevent illness which 32 (29%) students chose. Although none of the distractors describe jobs assigned to the Medical Team, this item difficulty value, coupled with the unacceptably low discrimination value of 11% makes this a poor test item.

ITEM 10

On Item 10 which tested knowledge of Comet Halley's orbit, 40 students (37%) correctly answered that Comet Halley orbits the Sun about every 76 years. The most frequently chosen response was that the comet orbited around the Earth every 76 years. Although this item difficulty value is rather low, the test-maker considers this vital information to be presented in a straighforward manner and considers this test item a good one. The item discrimination value is an excellent 62%.

<u>ITEM 11</u>

On Item 11, students were questioned as to one important job of the Remote Team and 63 (58%) correctly responded that it is to use robots and the glovebox to collect and analyze leaves. Again, none of the distractors described jobs performed to the Remote Team, but all distractors were chosen by at least 8 (7%) of the test-takers. The discrimination value for this item was 53%.

<u>ITEM 12</u>

Item 12 questions what abilities were most important for the entire space crew to possess to promote a successful space mission and 83 (76%) correctly responded that it was to communicate and work as a team. All distractors were indicated as correct responses and the discrimination value for this item was 37%.

NOTE: Item discrimination values were not calculated for Items 13 and 14 because the test groups were too small to reach any signigicant conclusions. The number of respondants to each set of Items 13 and 14 is indicated.

ITEM 13 (Probe Team)

This Item 13 asked the 16 members of the Probe Teams which part of the space probe acted as the "brain" and nine of them (56%) correctly answered that it was the Central Processing Unit (CPU). Four (25%) chose the Multiplexer and three (19%) chose the Radiation Detector, but none indicated the Transceiver as a correct response.

ITEM 14 (Probe Team)

This Item 14 presented a hypothetical situation in which the Probe is tumbling uncontrollably and asked the Probe Team members to choose which part of the Probe should receive the correction signal and seven students (44%) correctly chose to send it to the Gyro. All distractors were chosen on this item by at least two students (12%).

ITEM 13 (Life Support Team)

On this Item 13, the 16 members of the Life Support Teams were asked what needed to be added to neutralize a sample of water that had a pH of 11 and seven students (44%) correctly responded to add vinegar. Close in frequency of response were the six students who chose sodium hydroxide as the correct addition. During the simulated spaceflight the students worked with acidic samples and did add sodium hydroxide to neutralize them.

ITEM 14 (Life Support Team)

On this Item 14, which queried students on what solar light energy changes into when it reaches the solar panel, eight (50%) correctly responded that it was electricity. Four students (25%) chose heat and four chose colored light, but none chose filtered light as a correct response.

ITEM 13 (Isolation Team)

On this Item 13, the 16 members of the Isolation Teams were questioned as to why they used robots to handle hazardous materials and 14 of them (88%) correctly responded that it was because these materials are dangerous to human health.

ITEM 14 (Isolation Team)

On this Item 14, students were given five hypothetical Geiger Counter counts and asked to find the average amount of radioactivity. Six students (38%) correctly averaged the figures given. This item difficulty is a little low and might benefit from revision to make it less difficult for the average test-taker.

ITEM 13 (Medical Team)

On this Item 13 the 15 members of the Medical Teams were asked to identify the instrument used to count number of breaths per minute and 11 students (73%)

correctly identified this instrument as a respiration sensor. The distractors on this item did describe duties or other instruments used by the Medical Team.

ITEM 14 (Medical Team)

On this Item 14 the students were given hypothetical skin temperature measurements and asked to pick the one most likely to be the reading from the fingertips. Ten students (67%) correctly chose the lowest reading of 31.8 degrees C. All distractors were indicated as correct answers.

ITEM 13 (Communications Team)

On this Item 13, the eight members of the Communications Team were asked to identify one important job theie team was responsible for in Space Station and a large majority of seven students (88%) correctly responded that it was to control the color the cameras that sent images to Mission Control.

ITEM 14 (Communications Team)

On this Item 14, which asked students to identify one important job performed by the Communications Team in Mission Control, the same large majority of seven students (88%) correctly responded that it was to receive messages from Space Station and relay them to the right team.

ITEM 13 (Navigation Team)

On this Item 13, the 16 members of the Navigation Teams were queried as to how they knew they had found

Comet Halley during the simulated spaceflight. This item was concerned with the concept of star magnitude and only one student (6%) correctly responded that the comet, having the lowest relative magnitude, would be the brightest object in the starfield. Seven respondants (44%) did choose the distractor mentioning magnitude and were confused only by the magnitude/brightness connection. This was the most popular response. The low item difficulty value of this item makes it a poor test item and unacceptable for inclusion on future forms of the CHAT.

ITEM 14 (Navigation Team)

On this Item 14 which asked students to identify the part of Comet Halley into which they attempted to launch the space probe, eight students (50%) responded that any part of the comet would do. Three students (19%) correctly responded that they were trying to launch the probe into the area of low density. Because the item difficulty value is unacceptably low for this item, it needs to be revised for inclusion on future forms of the CHAT.

ITEM 13 (Remote Team)

On this Item 13, the 14 members of the Remote Teams were asked to calculate the volume of a meteoroid using the water displacement method. Given all necessary measurements, ten students (71%) responded correctly to this item.

ITEM 14 (Remote Team)

On this Item 14, students were asked what they learned from doing a chromatography test and seven students (50%) correctly responded that this test showed that green leaves contain other colors besides green.

ITEM 13 (Data Team)

On this Item 13, the nine members of the Data Teams were asked to identify one important job that their team performed in Space Station and seven students (78%) correctly responded that it was to record test results from the Life Support, Remote, and Isolation teams.

ITEM 14 (Data Team)

On this Item 14 which asked students to identify one important job of the Data Team in Mission Control, five students (56%) correctly responded that it was to write down who the message is for.

Of the 28 total items used on the CHAT, 23 items (82%) had item difficulty values above 40%. For the purposes of this study item discrimination values for Items 13 and 14 were averaged. Out of a total of 14 items, then, 13 items (93%) had a discrimination value above 20% A copy of the responses to each item on the CHAT for the entire test group is included as Appendix C.

CHAPTER V

CONCLUSIONS

Summary

The purpose of this study was to take the first steps toward the development of a valid and reliable multiple-choice test to be used in the formative evaluation of the Challenger Learning Center's (CLC) "Rendezvous with Comet Halley" scenario.

The Challenger Center is a unique educational initiative founded by the families of the crew members of the space shuttle Challenger as one attempt to combat a serious lack of science competency among American citizens. The Challenger astronauts lost their lives during a mission designed to inspire schoolchildren around the nation to appreciate the importance of science in their lives. At the CLC, students utilize problem-solving and cooperative learning techniques to complete a series of tasks necessary to complete a simulated space mission in the environment of a real spaceflight.

The Comet Halley Achievement Test (CHAT) evaluated student knowledge of selected scientific skills and concepts encountered through participation in the simulation. The CHAT included 14 items. Twelve of these items were administered to the entire test group.

In addition, two items contained information pertaining to the student's team assignment during the simulation. Construction of all items was based on the learning objectives developed by Challenger Center staff for the "Rendezvous with Comet Halley" simulation. A copy of the learning objectives is included as Appendix B.

The researcher hoped that the following test analysis goals would be reached: that the reliability coefficient as measured by the Kuder-Richardson Formula 20 (KR-20) would be .60, that each item difficulty value would be at or greater than 40%, and that each item discrimination value would be at or greater than 20%.

The KR-20 reliability coefficient was .61 (n=109). The item difficulty value was at or greater than 40% for 23 (82%) of the total 28 items. The item discrimination value was at or greater than 20% for 13 (93%) of the total 14 items for which this value was calculated.

The test group was comprised of 109 sixth-grade students attending school in the Dayton Public Schools, a predominantly urban school district in Dayton, Ohio.

Recommendations

Recommendation 1. Twenty-three of the total 28 items on the CHAT were analyzed to be acceptable test items. The researcher recommends that these 23 items be included on the CHAT as originally written.

Recommendation 2. Item 10 was analyzed to have an item difficulty value of 37%, near the unacceptable value level. The researcher recommends this item be included on the final CHAT as written, however, because it contains information vital and basic to serious study of Comet Halley and is written to clearly distinguish between more and less knowledgable students. The item reads as follows:

Item 10. Comet Halley orbits the

A. Sun about every 76 years.

B. Sun about every 24 years.

C. Earth about every 76 years.

D. Earth about every 24 years.

Recommendation 3. Four items: Item 9, Item 14 (Isolation), Item 13 (Navigation), and Item 14 (Navigation), failed to meet item difficulty standards established by the researcher for use in the pilot-testing of the CHAT. The reasearcher recommends that these four items be amended as follows. The original version of each of the following revised test items can be found in Appendix A.

Item 9. One important job of the Medical Team is to

A. make sure crew members have clean water and air to prevent illness.

B. check the food for unwanted bacteria before each meal.

C. make sure that no germs from outer space enter the Space Station.

D. study the physical effects of living onboard a Space Station.

The most frequently chosen response was a distractor concerning the Medical Team taking care of sick crew members. Because this was confusing for so many of the test-takers, this distractor has been eliminated and replaced with a new one (B.) concerning the safety of the food, a health related concern that is never mentioned during the simulation.

Item 14. (Isolation Team)

A Geiger Counter counts the number of radioactive particles given off by radioactive substances every 7.5 seconds. You have recorded the following counts: 5, 2, 8, and 9. The average amount of radioactivity of the sample is

A. 2.

B. 6.

C. 8.

D. 9.

The notable change to this item is that the number of counts in the stem has been reduced from five counts to four. Also, the responses have been arranged numerically and the correct response (6), no longer appears in the list of numbers needing to be averaged.

Item 13. (Navigation Team)

As a member of the Navigation Team, one of your duties was to locate Comet Halley. You knew you had found the comet when

A. an object of extreme brightness appeared in a starfield.

B. you saw an object as bright as Polaris.

C. you saw it streaking across the computer screen.

D. the Flight Commander told you it was there.

The concept of magnitude was a new one for the test group of sixth-grade students and they found it extremely difficult to distinguish between low magnitude objects being the brightest and high magnitude objects being less bright. The correct response is now the only response to include the concept of magnitude and the new distractor (D.), tests the student's committment to self-discovery.

Item 14. (Navigation Team)

The Navigation Team attempted to launch the space probe into the part of Comet Halley that had the lowest density. The area of low density on a comet is the

A. nucleus.

B. tail.

C. head.

D. coma.

This revised item is straightforward in its attempt to test knowledge of the variable density within a comet. The researcher hopes that including the concept of density in the stem and using the various parts of a comet as distractors makes the item more clear to the students.

Recommendation 4. The researcher recommends that there be a new administration of the CHAT incorporating the recommended changes to determine if these revisions affect the test's internal consistency.

Recommendation 5. The researcher recommends that a quasi-experimental study be conducted using the mean CHAT scores as the dependant variable. The researcher further recommends that the CHAT be used to compare the performance of three different groups.

Group I = students who receive controlled pre-flight orientation and participate in the Comet Halley scenario.

Group II = students who receive controlled pre-flight orientation and are tested on the CHAT prior to participation in the Comet Halley scenario.

Group III = students who receive no pre-flight orientation and are administered the CHAT following participation in the Comet Halley scenario.

Such a study would provide Challenger Center with relevant information on the relative impact of pre-visit materials and participation in the "Rendezvous with

Comet Halley" scenario.

Implications

As Challenger Center continues in its quest to increase scientific literacy among older elementary students, it is necessary that its programs be evaluated for effectiveness. It is the hope of the researcher that the development of the CHAT will serve as a valuable tool in conducting formative evaluation of the Learning Center programs in general and the "Rendezvous with Comet Halley" scenario specifically.

The expectations of Challenger Center is that it will make a difference in the way that middle school students look at science and technology. The scope of this difference is limited by the relatively short experience that students have at a Learning Center. To optimize the effects of problem solving through cooperative learning at a hands-on facility, it is vital that teachers feel comfortable with these techniques and incorporate them in their own classrooms on whatever scale is possible. Ultimately, this is what may do the most to further the common goal of a scientifically literate America.

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APPENDIX A

THE COMET HALLEY ACHIEVEMENT TEST (CHAT)

COMET HALLEY ACHIEVEMENT TEST

Choose the response that correctly completes each sentence. Write the letter of the correct response on your answer sheet.

1. It is important to study Comet Halley because
   A. it may carry life from other planets on it.
   B. we need to make sure it doesn't crash into the Earth.
   C. it might help us learn about the beginnings of the solar system.
   D. we need to find out why it keeps coming back.

2. A space station is
   A. a kind of laboratory in space. Astronauts can live in it and do scientific experiments in it without having to wear bulky spacesuits.
   B. the piece of equipment that was launched after the Navigation Team located Comet Halley. It will travel with the comet and do experiments.
   C. a kind of laboratory located on Earth. Astronauts can live in it to study about space and do experiments.
   D. a vehicle that is launched into space on a rocket, but is able to land back on Earth by itself.

3. Comet Halley, like all comets, is made up of
   - A. rock, ice, and gas.
   - B. rock, light, and heat.
   - C. water, light, and gas.
   - D. meteoroids, ice, and snow.

4. One important job of the Isolation Team is to
   - A. use robots to handle hazardous materials during the mission.
   - B. keep anyone who is sick away from all healthy crew members.
   - C. store human waste in a special area.
   - D. activate the meteor shields to protect the space station in the event of a meteor shower.

5. The most important job of the people in Mission Control is to
   - A. answer any questions from Space Station and ask questions about what Space Station is going to do next.
   - B. follow directions exactly as they are given and send test results to Space Station.
   - C. concentrate for long periods of time and analyze gas samples as soon as they are received.
   - D. carefully record the results of the experiments and help teammates in Space Station to complete their tasks.

6. The parts of comets are called the
   A. nucleus, cytoplasm, and cell wall.
   B. nucleus, coma, and tail.
   C. head, body, and tail.
   D. period, coma, and nova.

7. One important job of the Navigation Team is to
   A. make sure Comet Halley doesn't crash into the Earth or the space station.
   B. steer the space station to keep it in the correct orbit.
   C. find Comet Halley in space and launch the space probe into it.
   D. make sure the space station doesn't get too close to Comet Halley.

8. The most important job of the people in Space Station is to
   A. answer any questions from Mission Control and launch the space probe.
   B. follow directions exactly as they are given and send test results to Mission Control.
   C. sit for long periods of time and analyze gas samples.
   D. record data very carefully and help teammates in Mission Control to complete their tasks.

9. One important job of the Medical Team is to
   A. make sure the crew members have clean water and air to prevent illness.
   B. take care of anyone who is sick.
   C. make sure that no germs from outer space enter the space station.
   D. study the physical effects of living onboard a space station.

10. Comet Halley orbits the
    A. Sun about every 76 years.
    B. Sun about every 24 years.
    C. Earth about every 76 years.
    D. Earth about every 24 years.

11. One important job of the Remote Team is to
    A. make sure the space station doesn't wander off to unexplored areas of space.
    B. work with micrometeroid panels to find out if the space station is in danger from meteroid hits.
    C. study hazardous materials without touching them.
    D. use robots to collect leaves from the greenhouse and analyze them in the glovebox.

12. The success of any space mission depends mainly on the whole crew being able to

    A. carefully do an experiment right the first time.

    B. be brave in case there is a disaster on board.

    C. communicate and work as a team.

    D. fix any equipment that might break down during a flight.

Probe Team version

13. As a member of the Probe Team, you assembled a device to collect data from Comet Halley. The part of the probe that acted as the "brain" was called the

A. Multiplexer.
B. Transceiver.
C. Radiation Detector.
D. Central Processing Unit (CPU).

14. After being launched, the Probe begins to tumble uncontrollably. You need to send a correction signal to the Probe. To correct the problem you should send a signal to the

A. Transceiver.
B. Gyro.
C. Central Processing Unit.
D. Multiplexer.

Life Support Team version

13. As a member of the Life Support Team, you tested the pH level of some water. If a sample of water has a pH of 11 and you need to neutralize it, you would add

A. sodium hydroxide.
B. clean water.
C. indicator.
D. vinegar.

14. When light energy from the sun reaches the solar panel, the energy is changed into

A. heat.
B. electricity.
C. filtered light.
D. colored light.

Isolation Team version

13. As a member of the Isolation Team, you used robots to handle hazardous materials. This is because

    A. the robots could do the job more quickly.
    B. the robots were programmed to test the material correctly every time.
    C. the amount of material was too small for your eyes to see.
    D. touching hazardous materials is dangerous to human health.

14. A Geiger Counter counts the number of radioactive particles given off by radioactive substances every 7.5 seconds. You have recorded the following counts: 5, 2, 8, 9, and 6. The average amount of radioactivity of the sample is

    A. 9.
    B. 6.
    C. 4.
    D. 3.

Medical Team version

13. As a member of the Medical Team, you collected data about how many breaths a person takes each minute. You did this by

    A. counting heartbeats.
    B. attaching a skin probe to a person’s fingertip.
    C. counting breaths.
    D. using a respiration sensor.

14. You measured the skin temperature of crew members at three different parts of their bodies. Suppose you recorded the following measurments. Which is most likely the reading from the fingertips?

    A. 40.3 degrees C.
    B. 31.8 degrees C.
    C. 44.0 degrees C.
    D. 98.6 degrees F.

Communications Team version

13. One important job of the Communications Team in Space Station is to

    A. make sure all teams mics are working properly.
    B. control the volume of all team's headsets.
    C. make sure all teams are listening to the Mission Commander.
    D. control the cameras that send color images to Mission Control.

14. One important job of the Communications Team in Mission Control is to

    A. keep the mission status monitor focused.
    B. receive messages from Space Station and relay them to the right team.
    C. help teammates use the research computer.
    D. make sure all teams are listening to the Flight Director.

Navigation Team version

13. As a member of the Navigation Team, one of your duties was to locate Comet Halley. You knew you had found the comet when

    A. an object of extremely high magnitude appeared in a starfield.
    B. you saw an object as bright as Polaris.
    C. you saw it streaking across the computer screen.
    D. an object of extremely low magnitude appeared in a starfield.

14. The part of Comet Halley into which the Navigation Team attempted to launch the probe was

    A. the area of high density.
    B. the area of low density.
    C. the nucleus.
    D. any part of the comet.

Remote Team version

13. As a member of the Remote Team, you measured the volume of a meteoroid. Suppose a graduated cylinder has 160 mL of water in it and you put a meteroid into it. The volume of the water and the meteoroid measures 235 mL. The volume of the meteoroid is

A. 23 mL.
B. 395 mL.
C. 50 mL.
D. 75 5mL.

14. You used alcohol to take the chlorophyll from a leaf and then did a chromatography test. From this test you learned that

A. green leaves contain <u>no</u> other colors besides green.
B. green leaves contain other colors besides green.
C. even brown leaves have some green in them.
D. it is dangerous to touch alcohol with your bare hand.

Data Team version

13. One important job of the Data Team in Mission Control is to

    A. contact the appropriate team as soon as the message begins so they can read the message right away.
    B. turn on the ImageWriter as soon as you start to get a message.
    C. use a dictionary to make sure you spell correctly.
    D. accurately record test results from the Life Support, Remote, and Isolation teams.

14. One important job of the Data Team in Space Station is to

    A. make sure team files don't get mixed up.
    B. write down who the message is for.
    C. make sure all teams in Space Station do their experiments in the right order.
    D. keep the color cameras focused.

APPENDIX B

LEARNING OBJECTIVES OF THE "RENDEZVOUS WITH COMET HALLEY" SCENARIO

Learning Objectives

Rendezvous with Comet Halley in 2061

Students participating in the Rendezvous with Comet Halley in 2061 mission will be involved in an educational experience that includes:

- **"hands on" problem solving activities** - Activities that require operation of equipment, making critical measurements, and other related tasks required to collect necessary data or to complete necessary operations.

- **cooperative learning** - Students solved problems by working as team members rather than as individuals, as team members the students have certain assigned roles and responsibilities.

- **application of math and science skills** - Team members collect data in the space station using science skills such as observation and measurement. The data will be analyzed back in the classroom. The interpretation of the data requires the use of mathematics and science to carryout or solve the various tasks and problems.

- **use of communications skills** - Students must use both written and oral communications to carryout the mission. Students must follow directions and ask the right questions to get the "right" information to complete specific task.

- **creative and critical thinking skills** - Students must use different approaches to complete the various tasks during the mission, approaches that call for creative solutions and higher level thinking skills necessary to analyze and interpret the data collected during the mission.

- **introduction to science and mathematics related careers** - Throughout the mission students learn first hand about technology, science and mathematics leading to an introduction of the extensive variety of career opportunities involved in the space program.

- **the importance of space exploration** - Each flight has mission specific concepts stressing the importance of space exploration on solving Earth's problems or leading to a better understanding of our universe.

The following objectives are specifically related to the Comet Halley mission. The attainment of the objective is dependent not only on taking the flight, but also on completing the Pre- and Post-visit activities. Some of the objectives are specific to the particular team on which the student is a member during the mission. Others are generally applicable to the whole class in terms of gaining a greater understanding of comets and applying that knowledge in new ways.

Given the opportunities to participate in the Rendezvous with Comet Halley in 2061 mission and associated Pre- and Post-visit activities in the classroom at least seventy-five percent of the students will be able to successfully complete the related objectives.

I. Understanding and application of information about comets.

- be able to define rendezvous and list at least one reason why a rendezvous with Comet Halley is beneficial.

- be able to identify and describe the following parts of a comet: tail, nucleus, and coma.

- be able to write a paragraph describing the history of Comet Halley.

- be able to write a paragraph explaining why it is important to study comets.

- be able to describe Comet Halley's orbit and to locate Halley's position on a chart from 1986 to its next apparition in 2061.

- be able to plan a mission to do an experiment related to comets.

- be able to plan a mission for Comet Halley that will take it to beyond the Oort cloud into interstellar space.

II. Understanding of roles and responsibilities required to carryout a space mission.

- be able to list at least five roles and responsibilities of mission control and the Space Station (spacecraft in space).

- be able to state at least three ways being a member of a team can help solve problems easier than if attempted alone as demonstrated in the Comet Halley mission.

- be able to describe at least two systems included in a Space Station to ensure the safety of the crew.

- be able to list five careers associated with science or mathematics as demon strated from the Comet Halley mission.

- be able to describe in written or oral format the importance of communica tions and following directions to the successful completion of a mission.

III. Understanding their team's roles and responsibilities in the Comet Halley mission.

All team members will be able to describe their roles and responsibilities during the mission.

Communications Team Members
- be able to successfully communicate the needed information required during the mission.

Navigation Team Members
- be able to locate Comet Halley in space during the mission and successfully launch the probe to flyby Halley's nucleus.

Life Support Team Members
- be able to make measurements related to determine quality of water, energy, and repair the oxygen system to ensure the safety of the crew.

Medical Team Members
- be able to make "health" related measurements of selected crew members.

Probe Team Members
- be able to complete the assembly of the space probe to flyby Halley's nucleus.

Remote Team Members
- be able using robots to secure leaves from the greenhouse to analyze by paper chromatography in the glovebox.

Isolation Team Members
- be able to use teleoperations of robots to handle "hazardous" materials during the mission.

APPENDIX C

COMET HALLEY ACHIEVEMENT TEST RESPONSE DATA

CHAT RESPONSE DATA

ID#	Item 1-15*	ID#	Item 1-15*
42	411112242323421	53	111112341323421
48	331142342113322	51	311142324143421
41	231122344343422	83	311122341343421
62	311142324133141	21	321112422243142
44	311142324313241	24	311142113343122
21	331142344143412	29	321122224123421
24	311442322333422	22	311122122343421
51	311142324134421	72	311143212141422
53	311142342333421	74	321142322143422
75	411142342343421	76	311112222141421
76	311142322143432	78	311142321144421
74	311142322143431	22	211112322143422
27	331142332343422	28	211322322143422
21	331142322343421	24	311112323143442
26	331142332343422	27	311112323143422
29	311122342143421	11	211112122123332
31	431142242243422	14	314112311344421
12	231122342113422	12	311122323143421
14	31114232233 2	21	311442342142121
11	311142324143441	45	311142322313142
16	311112343343421	42	311142124343422
24	311142341343241	62	411112312343231
15	311142311143121	15	331113312343321
16	231412121243112	65	411142322143342
14	311114221224422	54	311142322343121
12	231421122341431	41	311112322112112
44	231123411421342	44	311242342343421
47	331112241143421	61	131112322123232
42	331122341144421	62	324132141333141
41	311142314343412	63	324113423142311
61	311142321143141	64	334114341343142
58	131142341323142	31	214112312323221
62	321442341113222	41	321141142441422
11	231412322232411	42	432112344332421
21	111142224121431	48	231122131131431
24	211112321443411	44	331132342 23422
28	311432242123221	15	343112441233441
29	221122133243441	14	332132241223112
26	2311133142334 12	12	31412234122333
22	131122341121412	11	331112211323111
71	431121342243112	21	324122222243412
71	324433424444142	24	31111232114342
79	431132421143441	22	331142112433421
74	321112321343421	26	311142312433121
21	231424322443142	21	214112424323311
26	131423244222311	26	313112213442341
27	331412214422122	29	312142221213422
28	313122344343441	71	22111231434242
22	331142322313111	76	42114212 23211
24	311312342133112	78	314442424342132
71	314413322143122	81	334143122342412
72	311142341443422	81	314312342333421
21	321142341233422	84	341111121441432
64	311112311133422	21	332142341133121
64	311442322343422		

*Item 15 = Sex of test-taker.

Identification Numbers

11-18 = Probe Team members

21-28 = Life Support Team members

31-39 = Isolation Team members

41-49 = Medical Team members

51-59 = Communications Team members

61-69 = Navigation Team members

71-79 = Remote Team members

81-89 = Data Team members